FAA/RD-94/19

Research and Development Service
Washington, DC 20591

Civil Use of Night Vision Devices - Evaluation Pilot's Guide Part II

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July 1994

Final Report

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JUL 13 1994

Dear Colleague:

Enclosed for your information is a copy of the recently published report **FAA/RD-94/19, Civil Use of Night Vision Devices - Evaluation Pilot's Guide, Part II.**

This report is one of three documents that were developed for evaluating the use of night vision goggles (NVG's) by EMS helicopter pilots. The other two reports are

FAA/RD-94/18, Civil Use of Night Vision Devices - Evaluation Pilot's Guide, Part I

FAA/RD-94/20, Assessment of Night Vision Goggle Workload - Flight Test Engineer's Guide

These three documents were written for a narrow audience of people involved in a specific flight test. However, they do have broader applications in terms of defining a useful way to collect data using non-technical subjects. The approach taken in this testing may provide some creative guidance in other flight tests. These reports are published with that thought in mind.

Using these documents, Government and EMS industry pilots participated in a flight test program to assess the use of NVG's in EMS operations. Information produced by other government agencies with extensive NVG operational experience was also reviewed for its application in EMS scenarios. Results of both the flight testing and the document review are documented in FAA/RD-94/21, Night Vision Goggles in Emergency Medical Service (EMS) Helicopters.

Robert D Smith

for Richard A. Weiss
Manager, General Aviation and Vertical
Flight Technology Program Office

Technical Report Documentation Page

1. Report No.	2. Gover nt Accession No.	3. Recipient's Catalog No.
DOT/FAA/RD-94/19		

4. Title and Subtitle
Civil Use of Night Vision Devices - Evaluation Pilot's Guide, Part II

5. Report Date
July 1994

6. Performing Organization No.

7. Author (s)
David L. Green

8. Performing Organization Report No.
91RR-44

9. Performing Organization Name and Address
SAIC
Systems Control Technology, Inc.
1611 North Kent Street, Suite 910
Arlington, VA 222091

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Federal Aviation Administration
Vertical Flight Program Office, ARD-30
800 Independence Avenue, S.W.
Washington, D.C. 20591

13. Type Report and Period Covered
Final Report

14. Sponsoring Agency Code
ARD-30

15. Supplementary Notes
Work was performed under subcontract by Starmark Corporation of Arlington VA.

16. Abstract
This document was developed to aid in the evaluation of the use of night vision goggles (NVG's) by civil helicopter pilots. This report was used to prepare pilots to participate in the flight test program. The principal task was to determine if there are any unresolved safety issues that would preclude pilot use of NVG's during helicopter operations under Federal Aviation Regulations Parts 91 or 135. Certainly NVG's can enable a pilot to "see better" at night and to accomplish certain flight objectives. However, the question is, is safety degraded during any phase of the flight operation if pilots use these devices. Even if the use of NVG's dramatically improves operational effectiveness, current safety margins must be maintained or improved during all phases of flight.

This report is one of three documents that were developed for evaluating the use of night vision goggles (NVG's) by EMS helicopter pilots. The other two reports are
- (1) FAA/RD-94/18, Civil Use of Night Vision Devices - Evaluation Pilot's Guide, Part I
- (2) FAA/RD-94/20, Assessment of Night Vision Goggle Workload - Flight Test Engineer's Guide.

17. Key Words	18. Distribution Statement
Night Vision Goggles, Helicopter, Pilot Assessment of NVG's, Pilot Workload	This document is available to the U.S. Public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	33	

TABLE OF CONTENTS

LIST OF FIGURES

PAGE

EVALUATION PILOT'S GUIDE (PART II) FOR COLLECTING CIVIL HELICOPTER PILOT ASSESSMENTS OF VFR APPROACH AND DEPARTURE OPERATIONS INVOLVING THE USE OF HELMET MOUNTED, NIGHT VISION DEVICES

INTRODUCTION

An FAA flight test team has been assigned the task of evaluating the use of a family of light intensification systems, generally referred to as Night Vision Goggles (NVG). This report was prepared to introduce subject pilots to the methodology and objectives of an operational flight test project established to assess the suitability of NVGs for civil helicopter operations. You have been given an opportunity to act as a subject pilot in this project.

This document serves to philosophically prepare the evaluation pilot to participate effectively in the flight program. The material also addresses proposed operational procedures and introduces the reader to the use of a subjective rating scale which has been tailored to meet the analytical and reporting objectives of this program.

Part I of this report addressed the use of NVGs during en route operations. The flight altitudes addressed were typically 500 feet AGL or higher. Part I also covered the conduct of reconnaissance having arrived at a remote area or any potential landing site with which the pilot was not familiar.

This part (Part II) treats the departures from and arrivals at, as well as take-offs from and landings on airports, heliports and remote sites.

PROGRAM OVERVIEW

The principal task of the FAA team is to determine if there are any unresolved safety issues which would preclude helicopter flights where pilot use NVG's during operations covered under Part 91 or Part 135.

The fact that these devices can substantially aid a pilot to "see better" at night and accomplish certain flight objectives is not in question. The question is, if pilots wear these devices, is safety degraded during any phase of the flight operation? You need to appreciate the fact that the goal of the FAA is to avoid degrading safety, over any portion of the flight. Even if the use of the goggles dramatically improves operational effectiveness throughout the flight, current margins of safety must be maintained.

There will always be a few pilots who will undertake irrational operations that they are not qualified to conduct safely. This project can not hope to preclude these operations. On the other hand, this project has a responsibility to investigate the potential for innocent blunders or traps. There are two causal factors for such situations which we will explore as examples. One factor involves errors which are the result of experimentation. A second cause involves an error in procedures. In particular, the failure to flip the goggles up at some point because the pilot forgot. That is, the pilot became very busy with the radio, or the pilot had to maneuver to avoid another aircraft, and forgot.

This evaluation is proposing procedures which are meant to define limits for the use of NVGs. It is important to determine that potential **violations of procedure**, whether intentional (experimentation) or unintentional (error of omission), **will not immediately place the pilot in a position where unusual pilot skill or technique will be required to re-establish safe flight** (following standard procedures). Any potential problem of this sort would require special training to qualify to use NVGs in flight.

The philosophy supporting the civil use of NVGs allows goggles to be used during normal visual flight operations, carried out under current regulatory authority. **The use of NVGs will <u>NOT</u> enable any mode of flight which cannot now be flown visually within the framework of existing FAA regulatory authority** . This is in stark contrast to certain military

operations such as Nap of the Earth (NOE) flight where the use of NVGs enables flight. NVGs will not enable any flight phase that you will evaluate. This does not mean that the NVGs cannot help you fly safer or more precisely. It means that from a legal point of view, the NVGs do not make flight possible. All operations must meet the stipulations in the FARs, as if NVGs were not used.

Suggested procedures have been established for you to follow in adjusting the NVGs to your eyes. Procedures have also been developed for you to follow during the flight evaluation. These procedures may not be 100 percent correct, but you will have an opportunity to suggest changes, once the team is sure that you understand the FAA's proposed constraints on the use of NVGs by civil helicopter pilots. **Your informed ideas for improving the use of the NVGs is sincerely solicited.**

Again, while there is no question that NVGs can help pilots see better under certain night flying conditions, there will always be limits to observe and there will always be right and wrong ways to do things. **This evaluation will look for limits, as well as right and wrong ways of doing things.**

RECOVERY FROM A PILOT BLUNDER

The FAA recognizes that pilots will err from time to time. These errors are sometimes errors in judgement or as the result of an event which distracted the pilot and caused him to break a habit pattern. Maybe the pilot is tired and shouldn't even be night flying. Regardless of the cause, the FAA recognizes such events do happen.

Realizing that such problems occur, the FAA expects that all operations are conducted with adequate margins of safety. That is, the margin of safety must be sufficient to allow a pilot who has blundered and recover from the blunder without undue hazard to the passengers, or to the aircraft, or to the people on the ground.

With the above in mind, there is a need to reflect on the potential miss application of the NVGs. It is recognized that an otherwise qualified (but bored or a highly inquisitive) pilot may experiment with NVGs. After some analysis, it would appear that take-off and landing operations represent the conditions where such experimentation could result in unsafe flight operations. This observation dictates that the potential of such operations should be explored.

Certain evaluation pilots will be asked to take-off from dark and lighted sites as well as land at dark and lighted sites, using NVG aided vision as the primary vision mode. The pilot may be asked to make "blunder" type errors on top of violating the procedure which precludes the use of goggles in the approach to landing and during a take-off. In particular, these events are explored to determine if there is any probability that a pilot will instinctively react in the wrong way. That is, instead of instinctively looking away from a bright light, is there any reason to think a pilot might become fixated on the light, or have any other potentially unsafe reaction? It would seem natural for a pilot to quickly look away from a light which degraded NVG aided vision to regain normal aided vision or to switch from aided to unaided vision (looking around the goggles). The related questions are so important, there is a need to determine the facts in flight. The idea is to check the reaction of real pilots (in a real flight situation) as opposed to relying on hypothesis.

In another case, a pilot might elect to attempt a landing with NVG aided vision. Is there any possibility that a pilot attempting to land with NVGs will touch down with sufficient drift to cause the aircraft to roll over (or any other such problem) before the pilot can recover to a hover? Is this possibility more likely to happen during NVG operations or when a pilot attempts to land with no lights at all? Which is more likely? Both would violate prudential rules for safe flight operations.

This evaluation must recognize that a pilot who attempts to land into a dark area, with no lights on, is in violation of safe and logical procedures. To attempt to use goggles under such conditions represents a second violation. This dual or compound violation would appear to be an irrational act and may be beyond the scope of interest to the FAA (other than to insure pilots were trained and tested as to their knowledge of the approved constraints for the use of NVGs).

DEPARTURE FROM A BRIGHTLY LIGHTED AIRPORT OR HELIPORT

The pilot is advised to check the prop .djustment of the goggles prior to the first night take-off. Having completed the adjustment, the pilot should flip the goggles up into the stowed position.

The pilot is expected to make a normal take-off and departure. Once at or above 300 feet AGL and stabilized comfortably in a climb, the pilot can at his/her option flip the goggles down into the bifocal viewing position. Was there at any time during this event, any tendency for an unsafe condition because the goggles were installed in the ready/stowed position?

Having just departed a brightly lighted area, maybe involving massive amounts of white light, the pilot may have a dark adaptation problem to deal with prior to starting to reference NVG vision. If the pilot has a dark adaptation problem, should the pilot delay flipping the goggles down and use them (in the bifocal mode)? If there should be a delay, why? If there is no need to delay, do the NVGs offer a preferable alternative to a prolonged period of impaired, unaided night vision? If not, why?

Should a pilot elect to take-off with the goggles in the bifocal position (against procedure), is there any reason to anticipate the possibility that a pilot might encounter a light which would result in unsafe operation of the aircraft? This question is asked recognizing that the pilot

always has the option to look under the goggles or flip them up or look away from any light. For some unexplained reason in this situation (to be evaluated), the pilot has momentarily looked through the goggles at a bright light. Is it likely that a reasonable trained pilot would for any possible reason fail to pursue a rapid recovery technique having experienced the difficulty hypothesized above? If yes, explain. If yes, is there any alternative remedy not suggested above? Is there any reason that the pilot could not immediately revert to unaided vision? If yes, explain.

PILOT PROCEDURES FOR TRANSITIONING <u>TO</u> BRIGHTLY LIGHTED AREAS

The pilot can use the NVGs to help dete and identify brightly lighted landing sites. Normal procedures dictate that the pilot should flip the goggles up prior to initiating a descent profile designed to position the aircraft for a final approach to a hover.

There is no procedural reason to keep the goggles down during a final approach or hover.

There is a possibility that a pilot might forget to flip the goggles up before commencing the approach. This would leave the goggles in the bifocal position. Having left the goggles in the bifocal position, there is no reason for the pilot to look through the goggles during the approach to a hover or during a landing. Assume the pilot left the goggles down in the bifocal position, does the light generated by the goggles interfere with the pilot's ability to look under the goggles and view the landing site unaided? If yes, how? If yes, is the problem a safety problem or is the effect more appropriately referred to as a nuisance of some sort (as you might feel a reflection is a nuisance or a flashing status light is a nuisance or static on a radio is a nuisance)?

Assume that there is some probability that a helicopter pilot may attempt to hover or land with night vision goggles down and attempt to fly the aircraft via reference to NVGs aided

vision. Recognizing that there are numerous red lights near most heliports and airports, and recognizing that bright red lights and certain white lights can cause the goggles to operate in a degraded mode, it is recognized that if a pilot persists in looking directly at a bright red light or certain bright white lights, the image available to the pilot may be inadequate to sustain or accomplish an adequate deceleration maneuver profile to a hover, or maintain a hover, or accomplish a vertical departure. Corrective action would involve a quick deflection of the pilot's line of sight (LOS) from the goggles to either side of the eye pieces, or below the eye pieces (a reversion to unaided vision). Alternately the pilot should immediately shift the LOS of the goggles away from the offending light. The questions are: (1) Is there any foreseeable reason that a pilot might inadvertently continue to look through the goggles, or purposefully continue to look through the goggles in mistaken perception that this was the best technique? If this happened, are there any traps which would prevent the pilot's immediate and uneventful reversion to one of the more appropriate techniques? If a pilot attempts to land with the goggles as the primary reference, is there any reason to think that this attempt might result in an accident of any kind?

ARRIVAL AND DESCENT IN PREPARATION FOR A NIGHT REMOTE SITE LANDING

Under normal, unaided night flying operations, a helicopter pilot is expected to arrive at a remote landing site and descend to a safe landing using natural light, lights on the ground and lights on the aircraft. NVGs are not to be used to land or even conduct an approach to a high hover (for this evaluation). Never-the-less, NVGs may be of significant benefits during the arrival, pre-descent phase.

First the pilot must find the landing site. This may mean looking for a lighted heliport or for a police car on a dark highway. Regardless, the pilot must descend to some safe (obstruction clear) altitude and verify the identity of the site and the appropriateness of the site as a

potential landing site. This process should include a high and low reconnaissance, to detect obstructions, to plan the approach path and to plan the departure. Trainable search lights, landing lights and fixed landing lights are usually used in this task.

This evaluation does not include the use of NVGs during an approach to a hover. The approach to a hover is adequately provided for via the conventional use of the conventional white lights discussed above. Conversely, the high reconnaissance phase could involve the coordinated use of NVGs and white lights. The military does not use white lights with NVGs. This is to avoid detection in combat, but there is nothing wrong with using some kinds of white lights in the civil environment with NVGs. We are interested in defining the best procedures "to use" and the procedures "to avoid" with ground illuminating white lights from high altitudes. We already know that staring into an auto's head lights with NVGs is not advisable. We also know staring into white lights with the naked eye will destroy night vision and is not recommended. We also know neither case is required. You look away in both cases. Tells us what you observe and how you scan the terrain from altitude, with and without white lights.

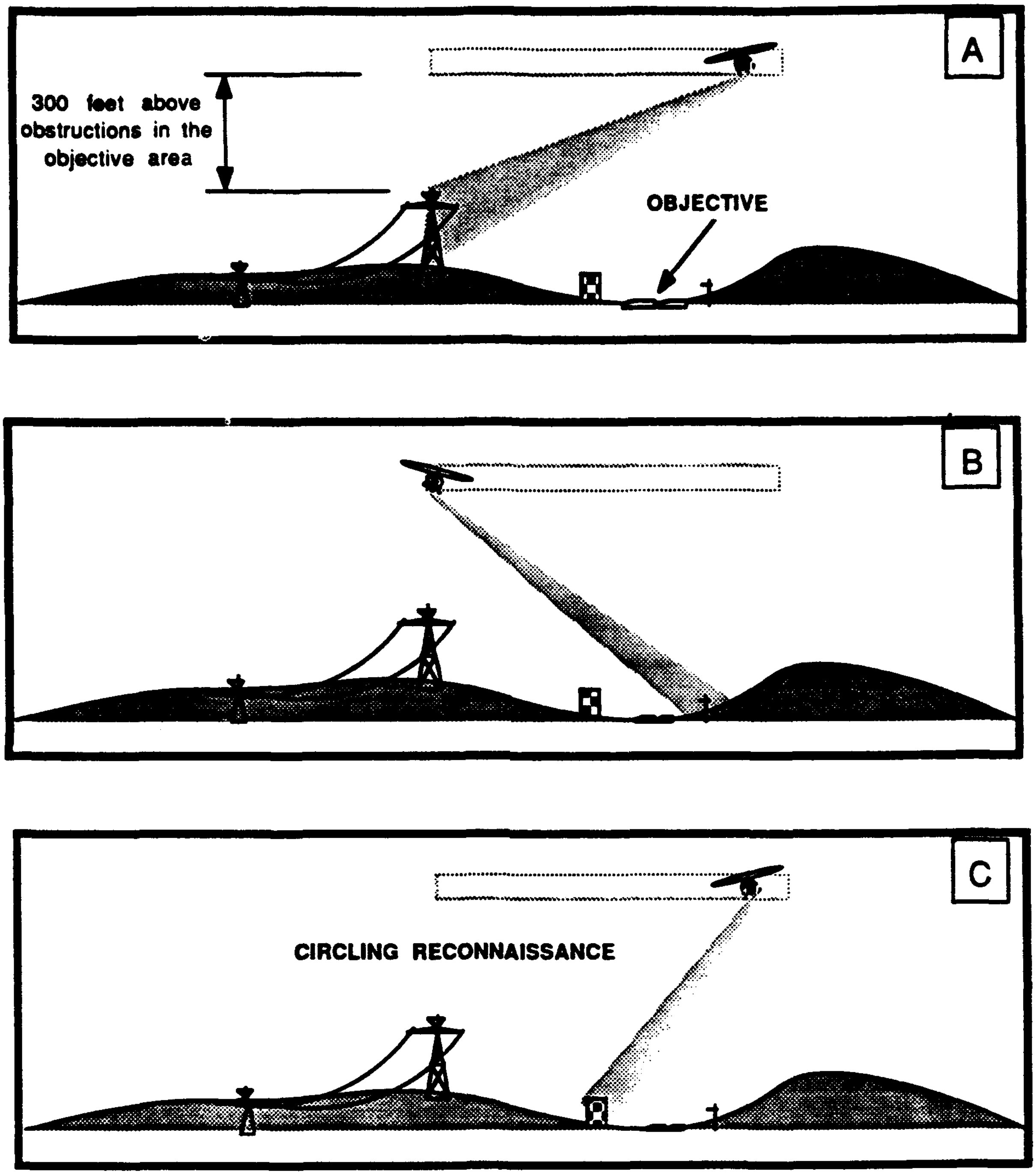

FIGURE 1: CONDUCTING A RECONNAISSANCE OF AN OBJECTIVE AREA

In Figure 1, the aircraft has descended to a lower altitude pre-planned for the high reconnaissance. This improves the ability of the search light to illuminate the immediate area and allow the pilot to detect hazards.

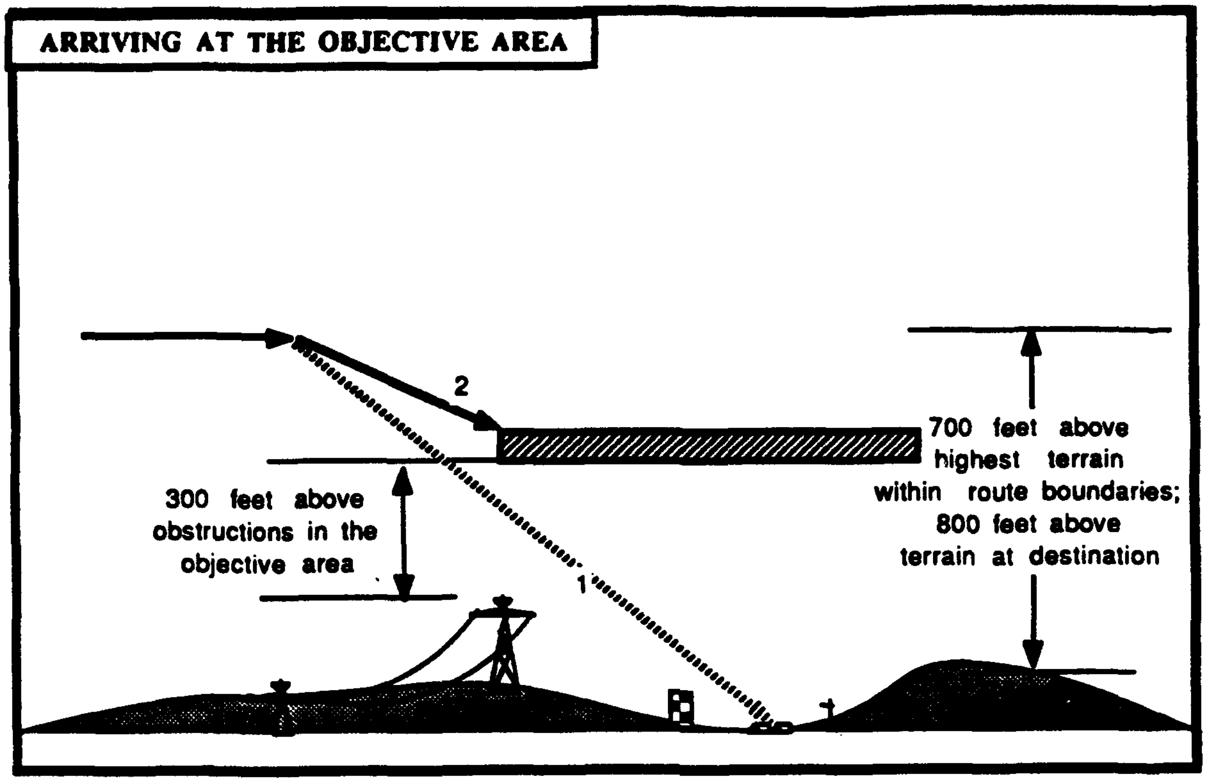

FIGURE 2: ARRIVING AT THE OBJECTIVE AREA

In Figure 2, an EMS helicopter has arrived in the area, conducted a search and has located an accident site (two cars, LOS "1" in Figure 2). Having located the site, the aircraft is flown down to a lower altitude ("2" in Figure 2) to continue a pre-approach, high reconnaissance. White lights are turned on before descending. It is important to make your transition from the dark night environment (with no lights) to the "white lights on" environment, before leaving the obstruction protected altitude established during your pre-flight and observed en route. This is true regardless of whether you wear NVGs or not. If it is a very hazy night, turning a white light on may produce a lot of backscatter. This may eliminate horizon cues and make the operation a bit less comfortable. Do NVGs improve or degrade night visibility when there is a heavy haze and a lot of backscatter?

As explained in Figure 1, spot lights can and should be used to look at objects on the ground while the pilot circles above. The pilot can look at the spot on the ground through the goggles and often see more than without the NVGs. The pilot also has the alternative of looking under the goggles and viewing the lighted area unaided. The resultant visual experiences will be different, but complimentary.

The pilot's head (with goggles) can be pointed at a number of different subjects (of potential interest) on the ground much faster and more accurately than the spot light. (The ability to focus the light to get a small or large spot, the candle power of the spot, and the articulation system of the light or lights obviously varies from light to light.)

Some features or objects may be easy to detect and interpret with the unaided eye. Other objects will be invisible to the unaided eye, yet easily detected and evaluated with NVGs. Each alternative viewing method has its attributes and its limitations.

In some cases, it may be desirable to flip the goggles up and out of the pilots eyes altogether. Flying low over a well lit city on a bright moonlight night would probably represent such a case.

When aided and unaided alternate viewing is desired, it may be best to adjust the goggles so that they are available for use in the same way bifocal glasses are used. That is, the pilot might adjust the goggles so that they are up and some what out of the primary eye line of sight. If this technique is used, the pilot's head must tilt forward to allow the pilot to look through the NVGs at the object of interest. While this is not a problem for most pilots, you may find a better way. The bifocal technique emphasizes that there is no requirement for a pilot to continually stare through NVGs, even when they are in the "ready", flipped down position.

OVERFLIGHT OF TERRAIN ALLOWS CREW TO LOCATE OBSTRUCTIONS AND SELECT APPROACH AND DEPARTURE PATHS

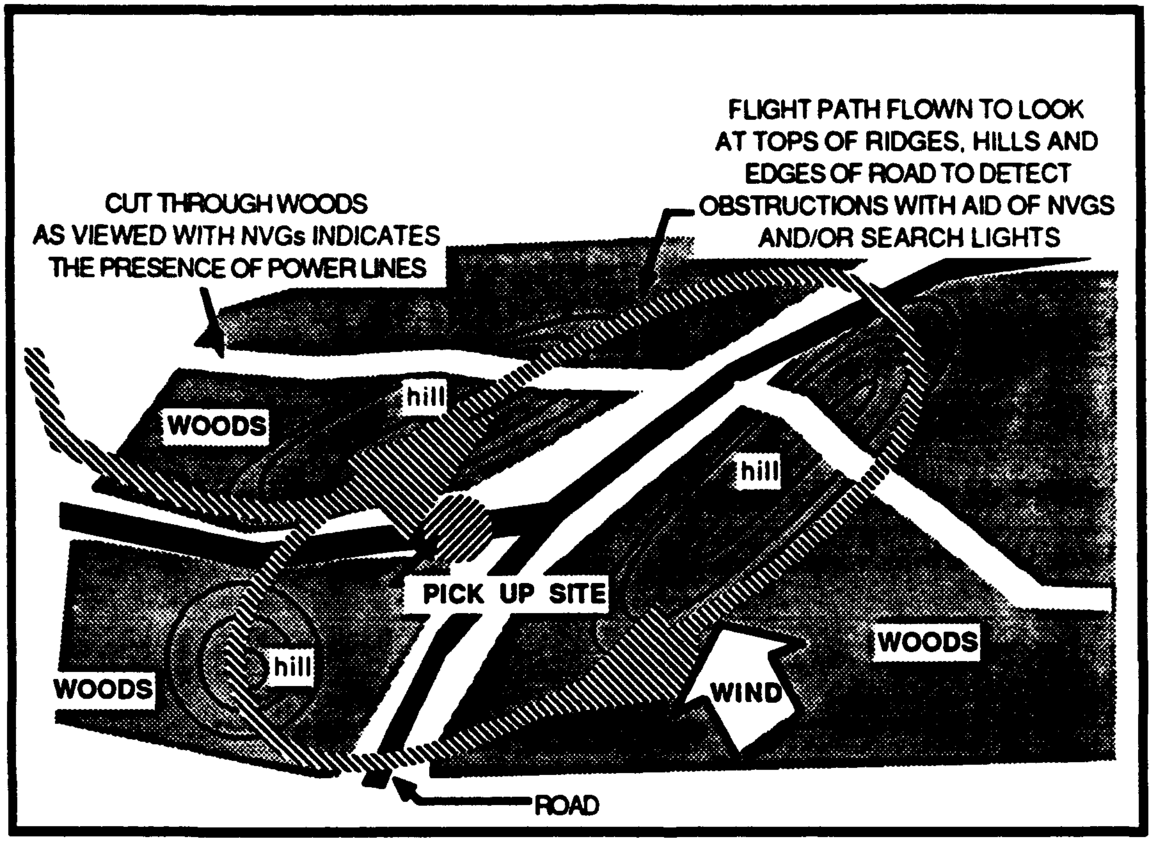

FIGURE 3: INITIAL RECONNAISSANCE FLIGHT PATTERN

This figure allows us to look down at the same scene presented in Figure 2. The pilot is flying an oval reconnaissance pattern and looking for tell-tails such as the cut through the woods which belies the presence of either a pipe line right-of-way or a power line right-of-way. The pilot picks a landing site and studies the terrain to evaluate alternative approach paths and departure paths. The pilot must be alert to the possibility that the wind may change direction and speed as the aircraft descends. The pilot may see a wire on short final and turn to use a different final approach path. Pre-planned alternatives are important.

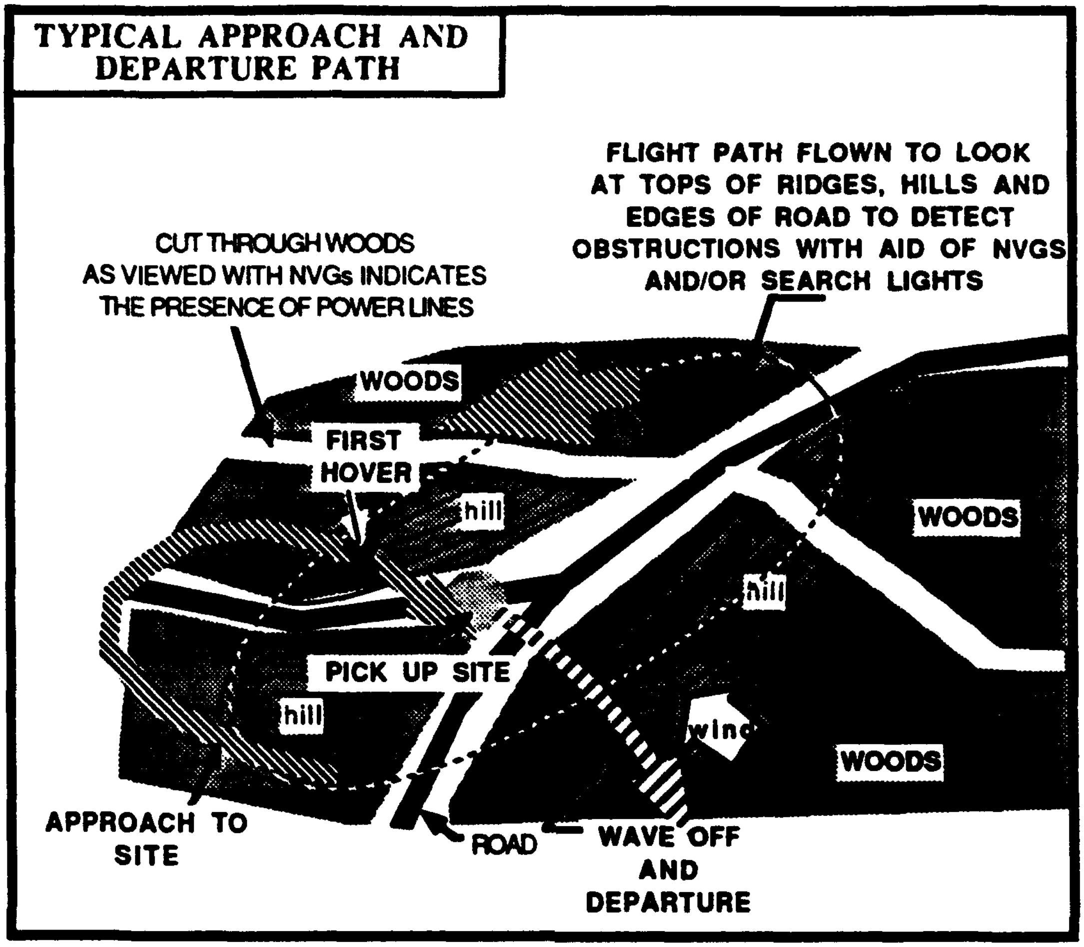

FIGURE 4: PLANNING AN APPROACH

Having completed the low reconnaissance, the pilot has selected a landing site and formulated a plan for conducting an approach. He has also made plans for an emergency abort (engine failure on approach), and has selected what looks like the best take-off departure route. The wind, terrain, landing site, obstructions and visibility have all been taken into account during this pre-approach effort.

To summarize, before starting the approach, the pilot may use the NVG's to help find and evaluate the obstructions in the area. This may involve bifocal type viewing where the pilot alternately looks under the goggles at what he can see with the spot light (unaided) and then he looks briefly through the goggles at the same spot, or on the edge of the spot, or elsewhere. When the pilot is ready to conduct the approach, the goggles are flipped up into a stowed position. Next, the floods may be turned on as the approach is commenced.

Although your evaluation ends after the reconnaissance phase (defined by the act of "de-goggling"), it is useful to remember that all lights are normally utilized during the descent-deceleration to a hover-landing. The pilot must sometimes adapt to the massive amounts of light, before descending into the obstruction rich environment.

FINAL APPROACH TO A REMOTE LANDING

The pilot is advised to follow the procedures characterized in Figure 5.

When the pilot concludes that he/she has completed the reconnaissance and is ready to conduct the final approach, the goggles are to be flipped up and flight is to continue with reference to white lights and unaided vision. The pilots eyes are expected to have already adapted to white light at this time. If there is any problem adapting, this problem needs to be defined in terms of safety.

The pilot is then advised to use standard procedures to complete an approach to a hover short of the intended landing site. This initial hover target is illustrated in Figure 5 as a hover box. The pilot uses this first hover (or near hover) to insure that speed is in fact under control and that there is an ample margin of power available to allow the pilot to get into and out-of the site (considering the available wind magnitude and direction). Once the pilot stops, the pilot is to conduct a quick check of the cockpit, looking at the power situation and completing other cockpit management tasks.

What if the pilot does not flip the goggles up until arriving at the first hover? Is this a potentially dangerous situation? If yes, why? If no, why? Once the error is discovered, can it be quickly corrected?

The rest of the approach and descent is of only academic interest to pilots but it is presented in Figure 5 for the information of engineers. It is meant to represent one way that a pilot might accomplish an approach to an obstructed remote site (it is not the only way).

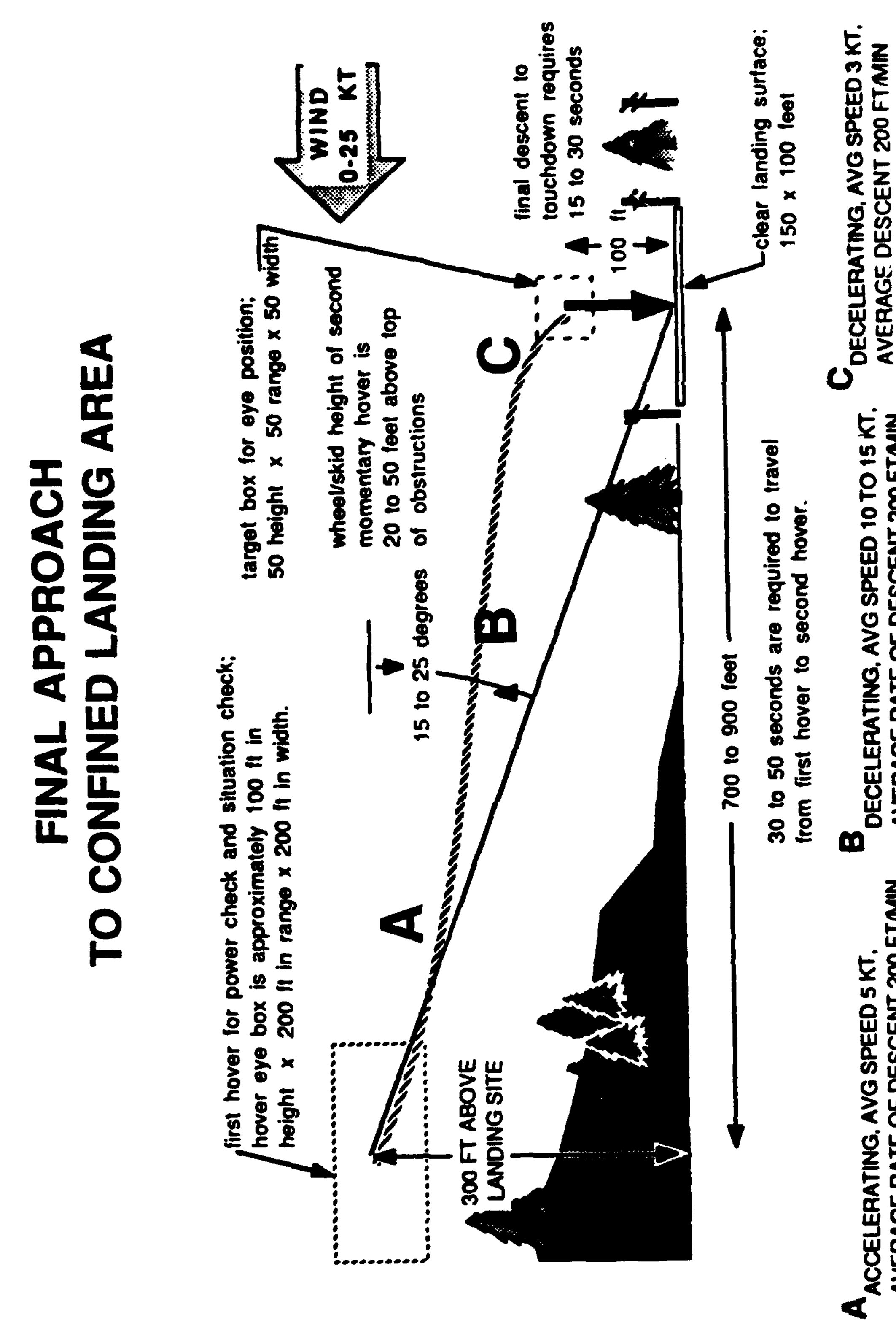

FIGURE 5: FINAL APPROACH TO CONFINED LANDING AREA

DEPARTURE FROM A DARK, REMOTE SITE

When a helicopter departs from a dark, remote site, the landing light is positioned to illuminate the flight path the pilot intends to follow.

If the site is bordered by obstructions, the aircraft will normally be flown through a vertical path to a high hover. Standard procedures involve an immediate departure from the high ho

The pilot should initiate the departure as a vertical climb with a gradual acceleration into forward flight.

The goggles are in the up and stowed position during the lift-off, during the assent to a hover and during the gradual acceleration to forward, climbing flight at best climb speed. Hover lights may be used but these are often not recommended, unless there is concern for drifting into obstructions during the climb. Such lights will delay the adaptation of the pilots eyes to the dark.

When the aircraft passes through 300 feet, in a climb to the en route altitude, and the pilot is comfortable with the status of the aircraft, the goggles can be flipped down into the normal inflight, bifocal viewing position.

It is possible that the pilot may violate procedure and prefer to take-off with the NVGs in the bifocal, normal operating position prior to and following lift-off. If this procedure is used, the pilot does not have to flip the goggles down after take-off. If a pilot decides to use this technique in violation of prescribed procedures. Will this result in a degradation in flight safety? If yes, why?

It is important to use good judgement to select the least amount of white light necessary to achieve adequate illumination during all phases of the departure. The use of minimum illumination offers the crew the best opportunity to become dark adapted as the aircraft rises into the night.

The massive use of white light may offer the best procedure to use during a take-off climb if there are numerous obstructions. Floods, landing lights and spots may be used. This approach requires the pilot to carefully secure the lights which interfere with night vision first. Total and sudden changes are not recommended.

The questions are: Do the night vision goggles enhance the shift from a "lights-on" condition to a lights-off condition? Does the presence of the goggles confuse the transition or otherwise degrade the pilots ability to manage the planned safe departure from the site? Would the pilot prefer to have the goggles down sooner? When? Why? Would the pilot prefer to have the goggles down later? When? Why?

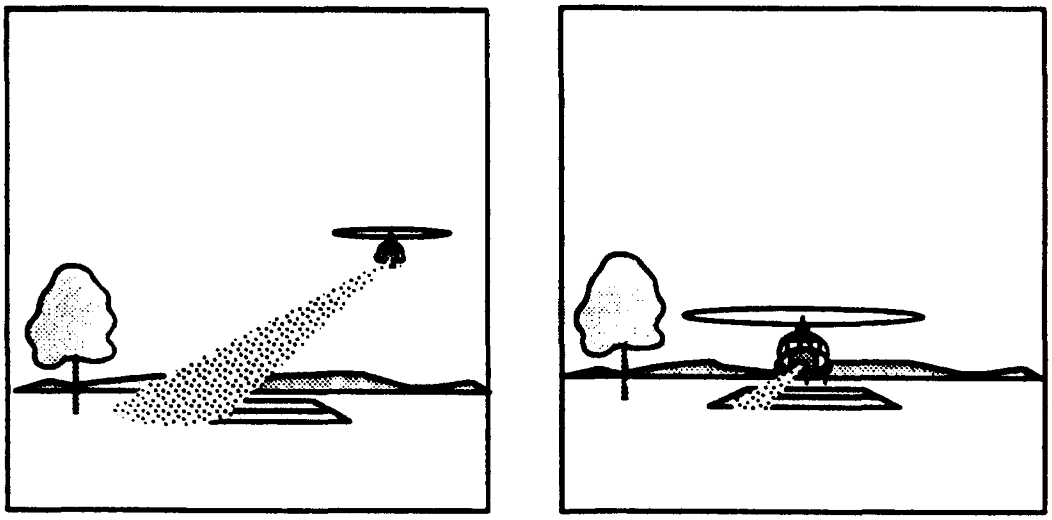

FIGURE 6: IDEAL NIGHT LANDING TO A PREPARED SURFACE

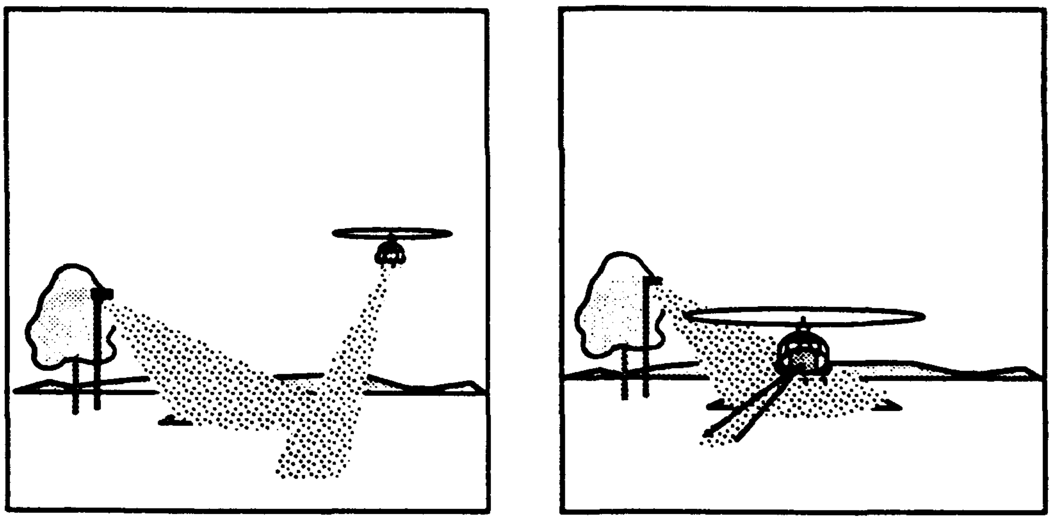

FIGURE 7: APPROACH TO LIGHTED HELIPORT WITH FIXED LANDING LIGHT

The following figures are included to help pilots and engineers visualize, in some organized way, the alternative situations which are possible when we consider the need or desirability of NVG operations involving take-offs and landings.

Figure 6 characterizes an approach to hover at night with a single fixed white landing light. The tree is not a meaningful obstruction but it does provide a useful cue to the pilot during arrival at the landing site.

Figure 7 introduces a pole mounted flood light, located so as to illuminate the landing site. These lights are found around buildings of airports and are often used to light hospital heliports. These lights help illuminate the pad from a distance, but in close, these lights shine into the eyes of pilots and degrade normal vision. They are at a mimimum, a nuisance factor. During post take-off operations, they may be more detrimental.

Figure 8 illustrates the use of a spot light to check for obstructions as the aircraft approaches a dark landing area.

Figure 9 introduces the application of one kind of flood light.

Figure 10 introduces the idea of natural light. Panels A and B involve a high full moon on a clear night Panel C is a quarter moon, D is a clear star light night and E dipicts operations under a heavy overcast.

Figure 11 involves added obstructions and a left cross wind.

Figure 12 is a reversed view of Figure 11 in a variety of natural light situations: A, high full moon; B, quarter moon; C, no moon, star light, clear; D, moon almost over head on clear night; E, moon low and in the pilots eyes during hover; F, no natural light, under a thick overcast.

Figure 13 provides a variety of horizon lines and lighting combinations: A, full moon over a high thin overcast; B, quarter moon over thicker cast; C, same as B but a low overcast which may be illuminated by city concealed by ridgeline; D, some over the shoulder light with a very dark distant sky; E, very dim over shoulder light, reflected light (from city) on thin, distant stratus clouds; F, dark.

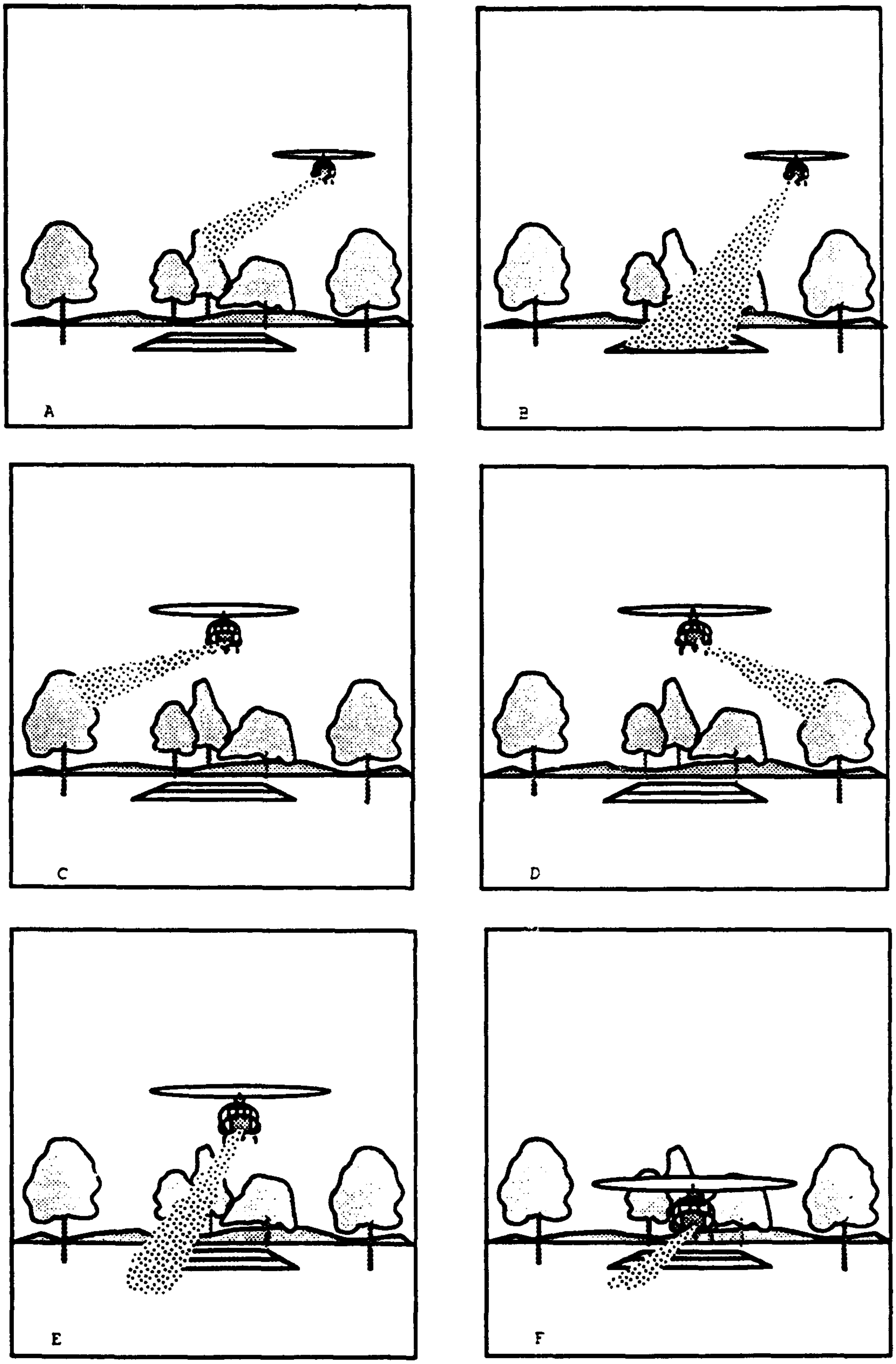

FIGURE 8: LANDING AT UNLIGHTED OBSTRUCTION BOUNDED SITE WITH SPOT LIGHT (An Observers View)

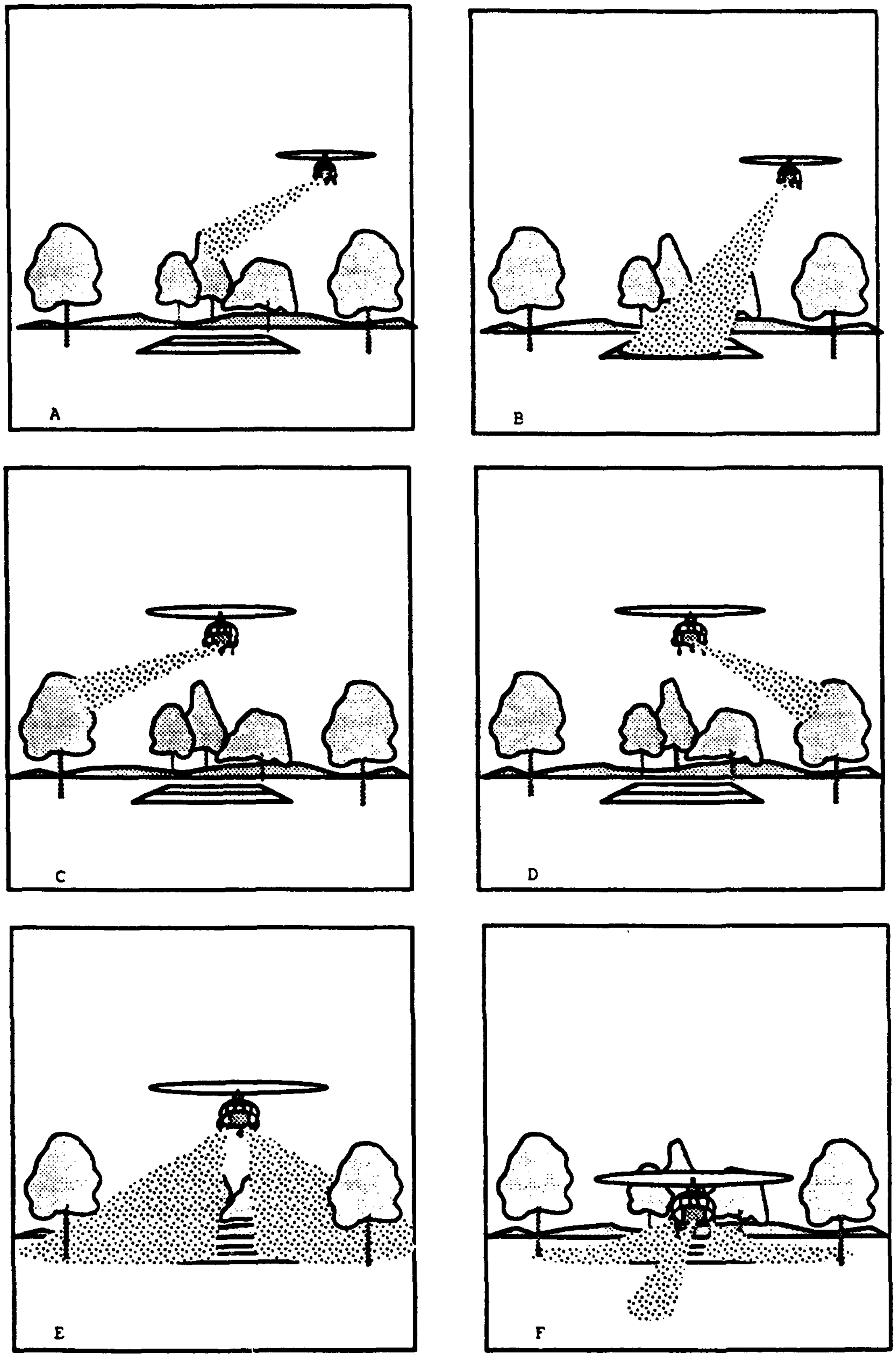

FIGURE 9: LANDING AT UNLIGHTED OBSTRUCTION BOUNDED SITE WITH SPOT AND HOVER FLOOD LIGHTS (An Observers View)

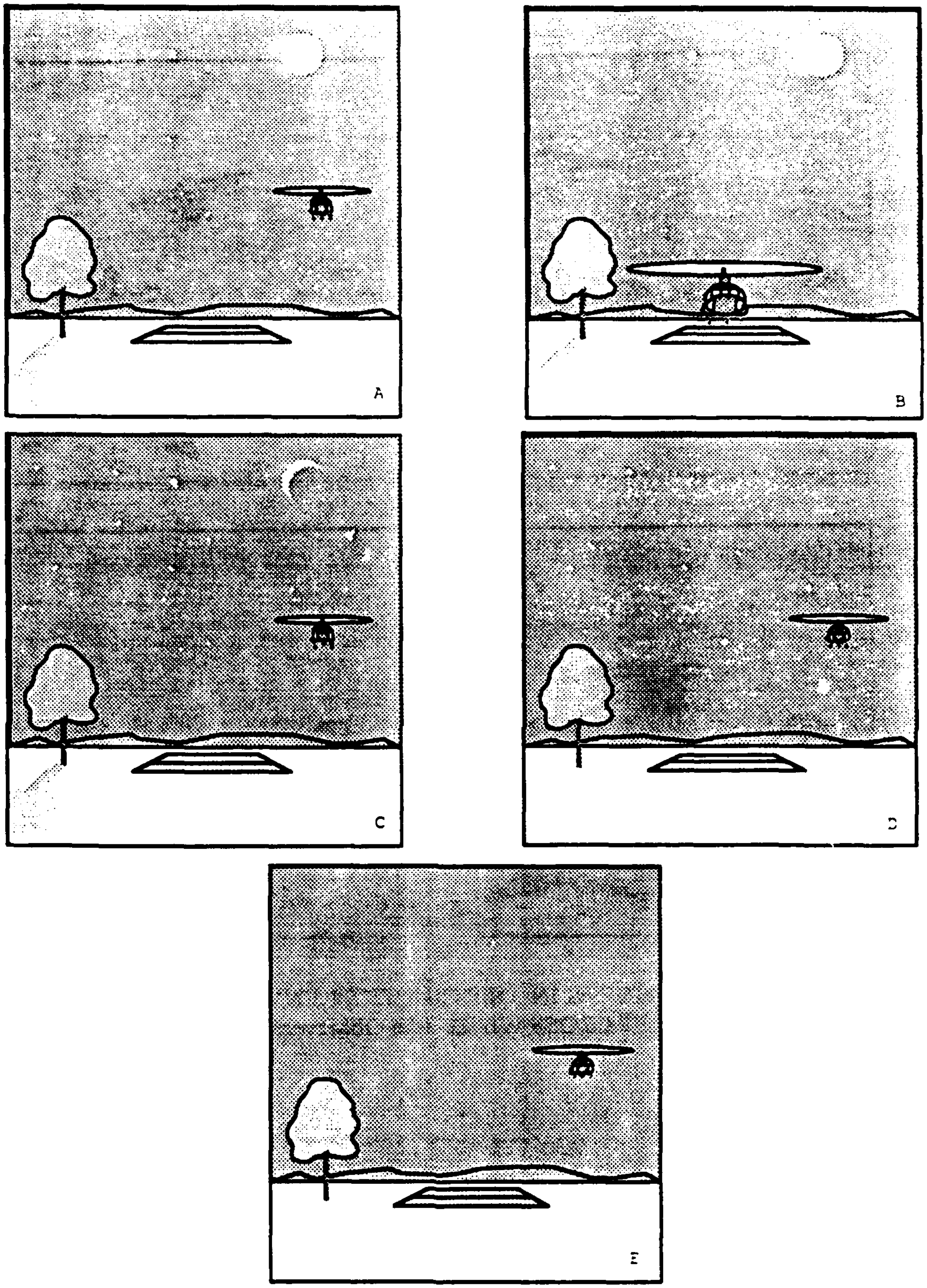

FIGURE 10: LANDING AT NIGHT IN FOUR NATURAL LIGHTING ENVIRONMENTS
(An Observers View)

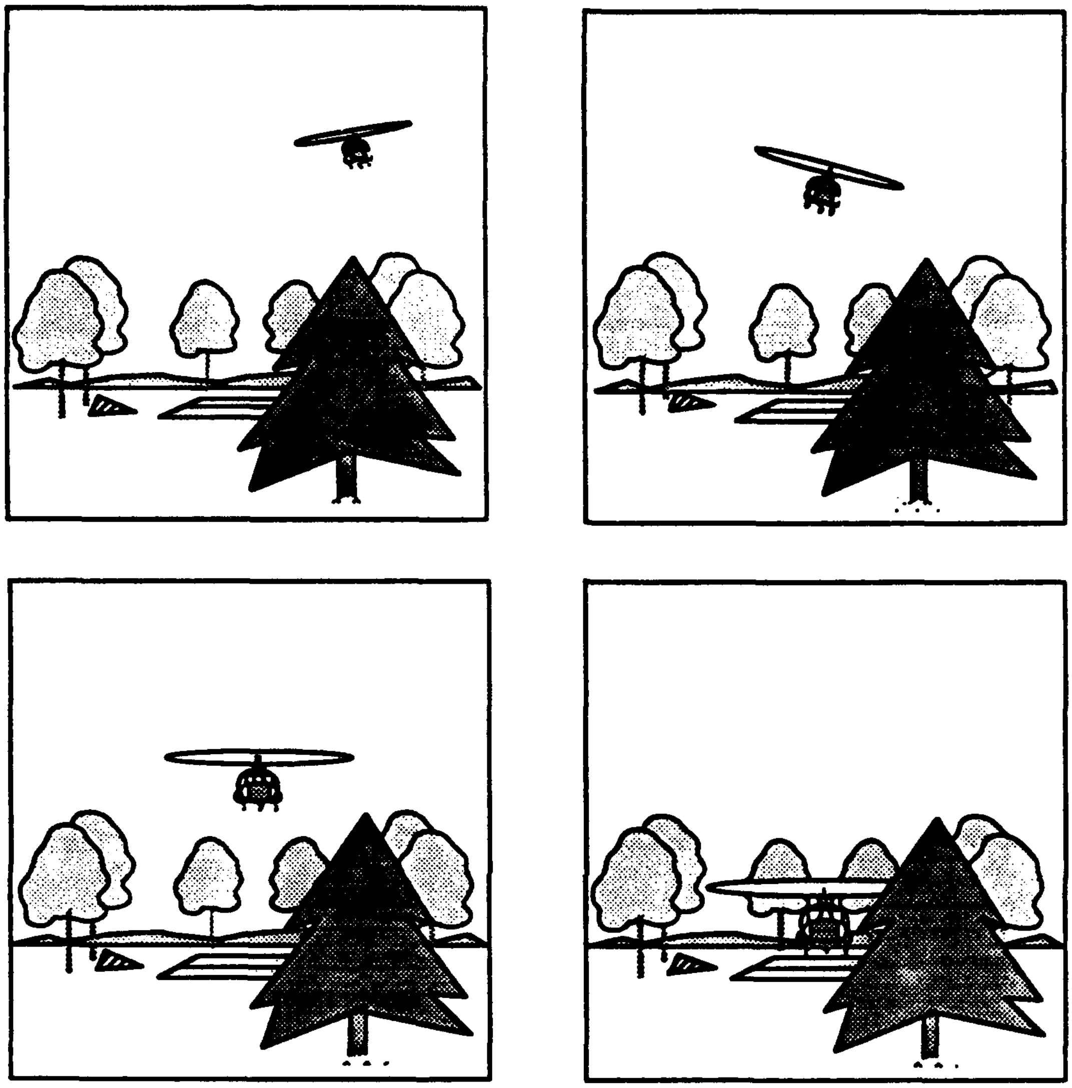

FIGURE 11: LANDING IN OBSTRUCTION ENVIRONMENT WITH LEFT CROSS WIND (An Observers View)

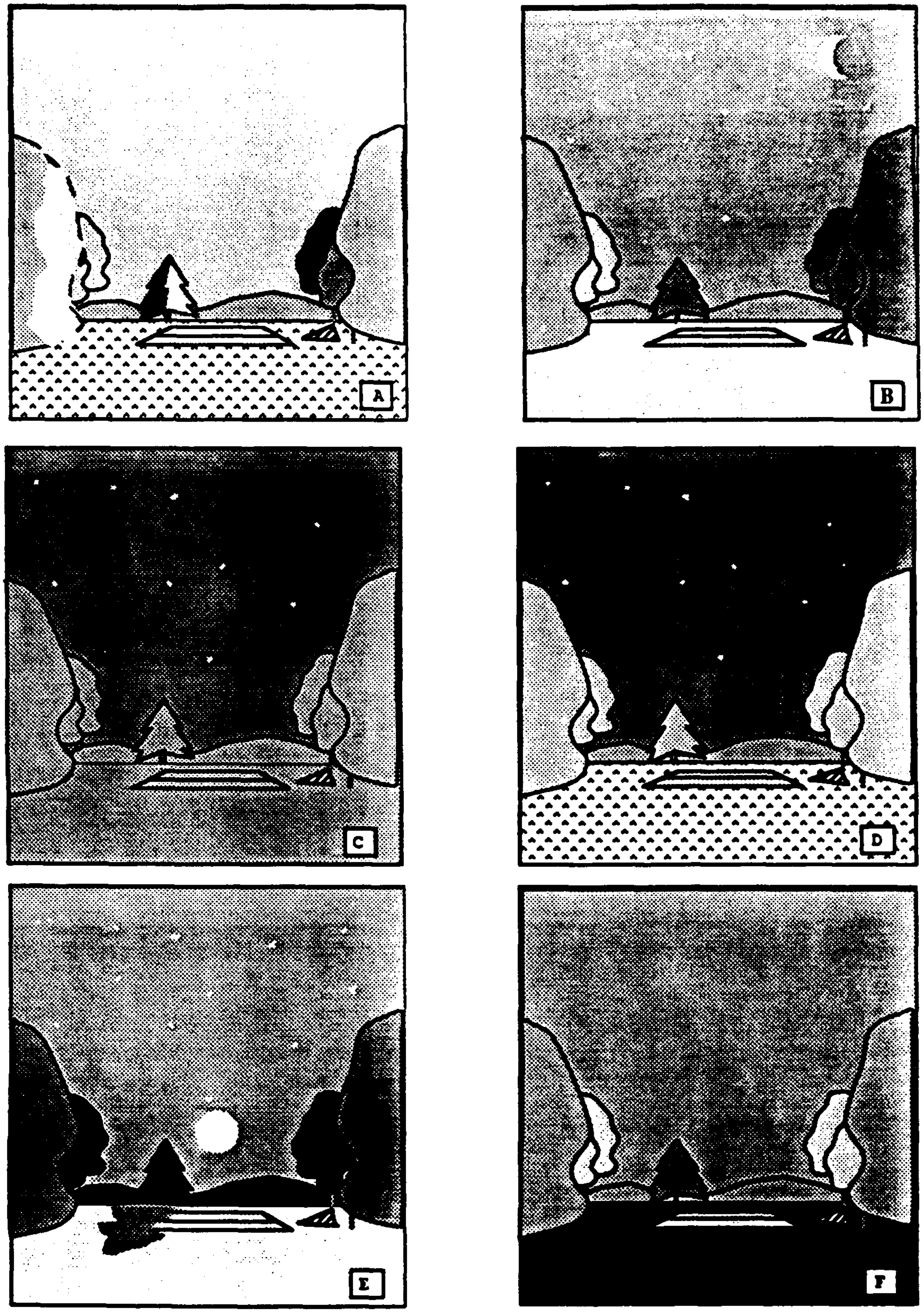

FIGURE 12: SIX LIGHTING ENVIRONMENTS ON A CLEAR NIGHT
(The Pilots View)

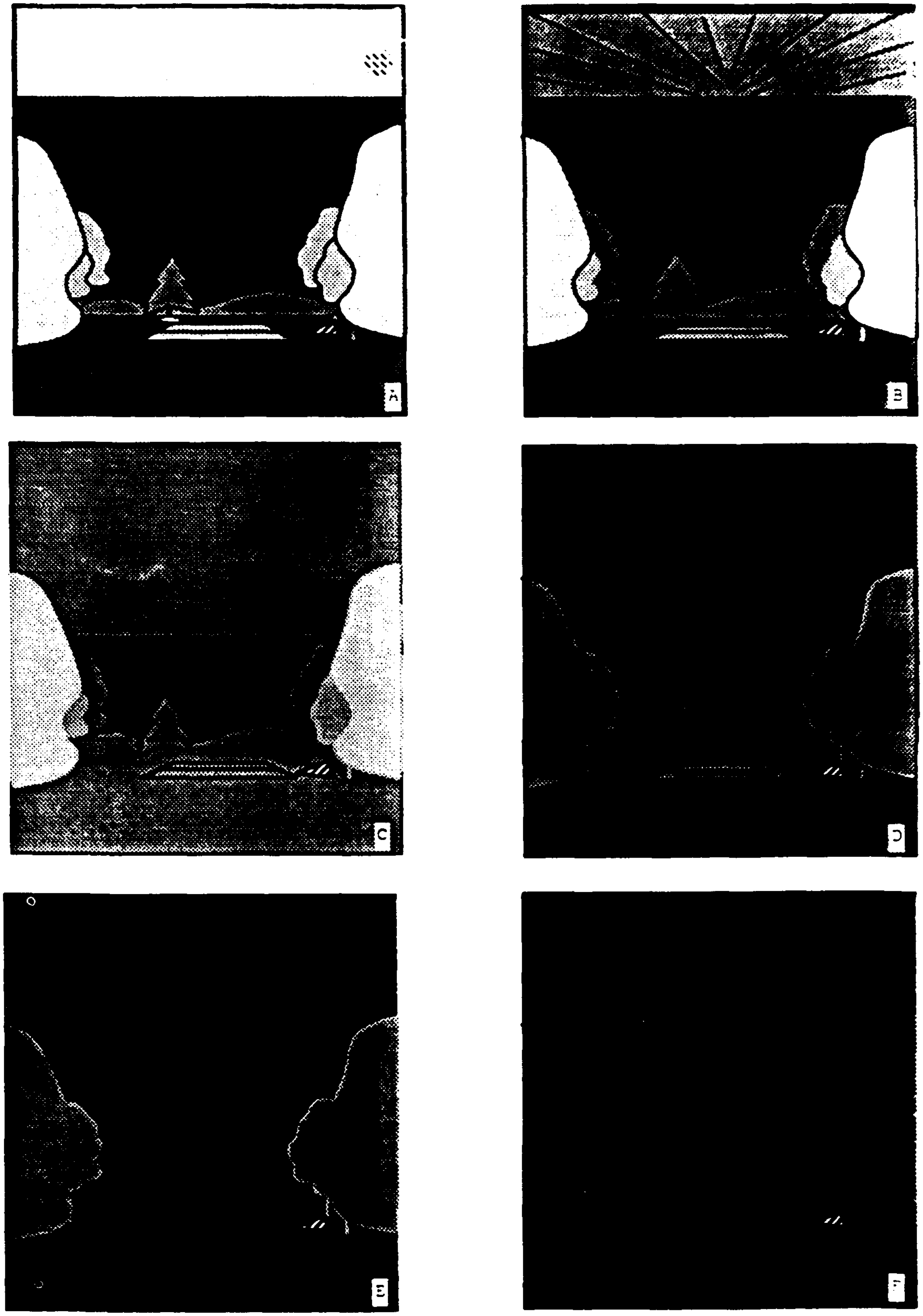

FIGURE 13: SIX LIGHTING ENVIRONMENTS ON A DARK NIGHT
(The Pilots View)